SWIMMING AND DIVING

5. **Oh, the pressure!**

Objective: Students will understand the pressures that whales are under when diving.

Level: 4-7

Background: The deeper down you go into the water, the greater the pressure. Whales have developed adaptations that allow them to survive in this environment. Some cetaceans can dive to incredible depths. The Sperm Whale (a toothed whale) is the champion diver of all whale species - it can dive deeper than 2000 metres and stay underwater for over 90 minutes. Sperm Whales have a unique adaptation for diving called the spermaceti organ. It is a large oil-filled sac in the head of the whale. As the whale descends into cooler water, its nasal passages, which are surrounded by the spermaceti organ, are filled with water. The cold water changes the density of the spermaceti and thus the buoyancy of the whale. By controlling the amount and temperature of the water the whale can control its buoyancy and remain neutrally buoyant at various depths. Baleen whales do not usually dive deeper than 90 metres, since their food is generally found in greatest concentration in the top 20 metres of water. But they can dive much deeper if they have to - up to 460 metres.

Whales have evolved other adaptations for diving in order to cope with the pressures of extreme depths. Research indicates that whales can take in about twice as much oxygen as other animals from a given volume of air. Whales have more red blood cells per unit of blood (almost twice that of humans) and the cells are larger than those in humans and other animals. These two factors allow for a speedy exchange of oxygen from the lungs to the haemoglobin -- the pigment in the red blood cells that carries oxygen. This oxygen supply is then transported throughout the body. Where whales differ from humans and other terrestrial animals is in their myoglobin content -- the oxygen-carrying pigment in the muscle. Whales show two to eight times as much myoglobin as terrestrial mammals; that's why cetacean muscle is much darker than beef and other animal meats. Since there is more oxygen circulating in the blood and muscles, a whale can have a continuous supply of oxygen to the heart and brain throughout the dive.

It is the oxygen-holding capacity of the muscle and blood that is the secret behind the whale's ability to perform long dives. It is not a factor of held breath as it is with humans. According to one estimate, total oxygen storage in a human diver is 34% in the lungs, 41% in the blood, 13% in the muscles, and 12% in other tissues. In the whale, the proportionately smaller and compressed lungs hold only 9% of the oxygen, with 41% in the blood, 41% in the muscles, and 9% in tissues.

When humans come up from a deep dive too quickly, they get what is known as the bends, or decompression sickness. If the diver doesn't decompress during the dive and expel some of the nitrogen s/he has taken in with the air, the expanding nitrogen can bubble into the tissues and cause dangerous, and possibly fatal, consequences upon surfacing. Whales don't get the bends like humans do, even though they make relatively deep dives with quick returns to the surface. One whale was recorded as routinely diving to 300 metres. Two factors protect whales from getting the bends. At depth, the air is compressed to a very small volume. As water pressure increases, the ribs, most of which are not strongly connected to the breast-

bone, collapse inward compressing the lungs and forcing air into nonabsorptive portions of the lung. Lung compression also reduces blood flow to the lungs. Both processes, and perhaps others, minimize absorption of air into the blood, preventing excessive quantities of nitrogen from dissolving in the blood. As the whale ascends, the compressed air expands again, refills the lungs, and blood flow and gas exchange resume. Also, the air the whale begins with is the air it comes up with, unlike SCUBA divers who are taking in compressed air (and compressed nitrogen) during the dive.

Whales also have other adaptations for diving. The heartbeat slows to about a tenth of its natural rhythm, and the temperature and metabolic rate of the whale decrease.

Materials: large can or carton, shallow bin, water.
Procedure:

1) Take a large can or carton and punch three or four holes in a vertical row from bottom to top, starting at least one-third of the way up the can.
2) Place the container in a shallow basin. Plug the holes and fill the container with water.
3) Unplug the holes and observe the differences in water streams from the top and bottom of the container. You will see that the greater pressure at the bottom of the container forces the water stream out farther from the wall of the container and that the top hole has a weaker stream.